Environmental determinants of West Nile fever in Europe and neighbouring countries

Annelise Tran[1], Bertrand Sudre[2], Shlomit Paz[3], Massimiliano Rossi[2], Annie Desbrosse[1], Véronique Chevalier[1], Jan Semenza[2]

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1 cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

2 ecdc
EUROPEAN CENTRE FOR DISEASE PREVENTION AND CONTROL

3 University of Haifa

West Nile virus

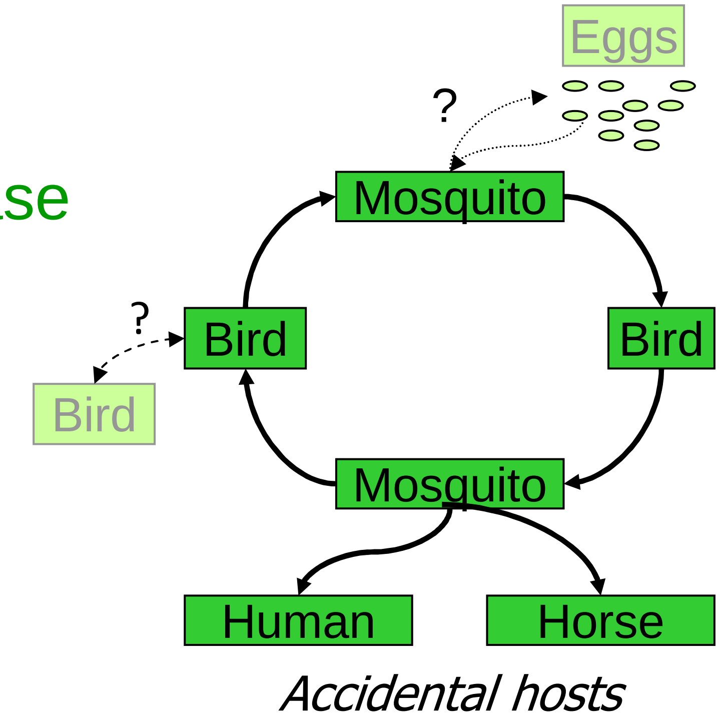
- *WNV:* flavivirus

- *WNF:* an emerging arbovirosis with a complex epidemiological cycle:
  - Birds
  - Mosquitoes (mainly *Culex* genus)
  - Horse and man: accidental hosts

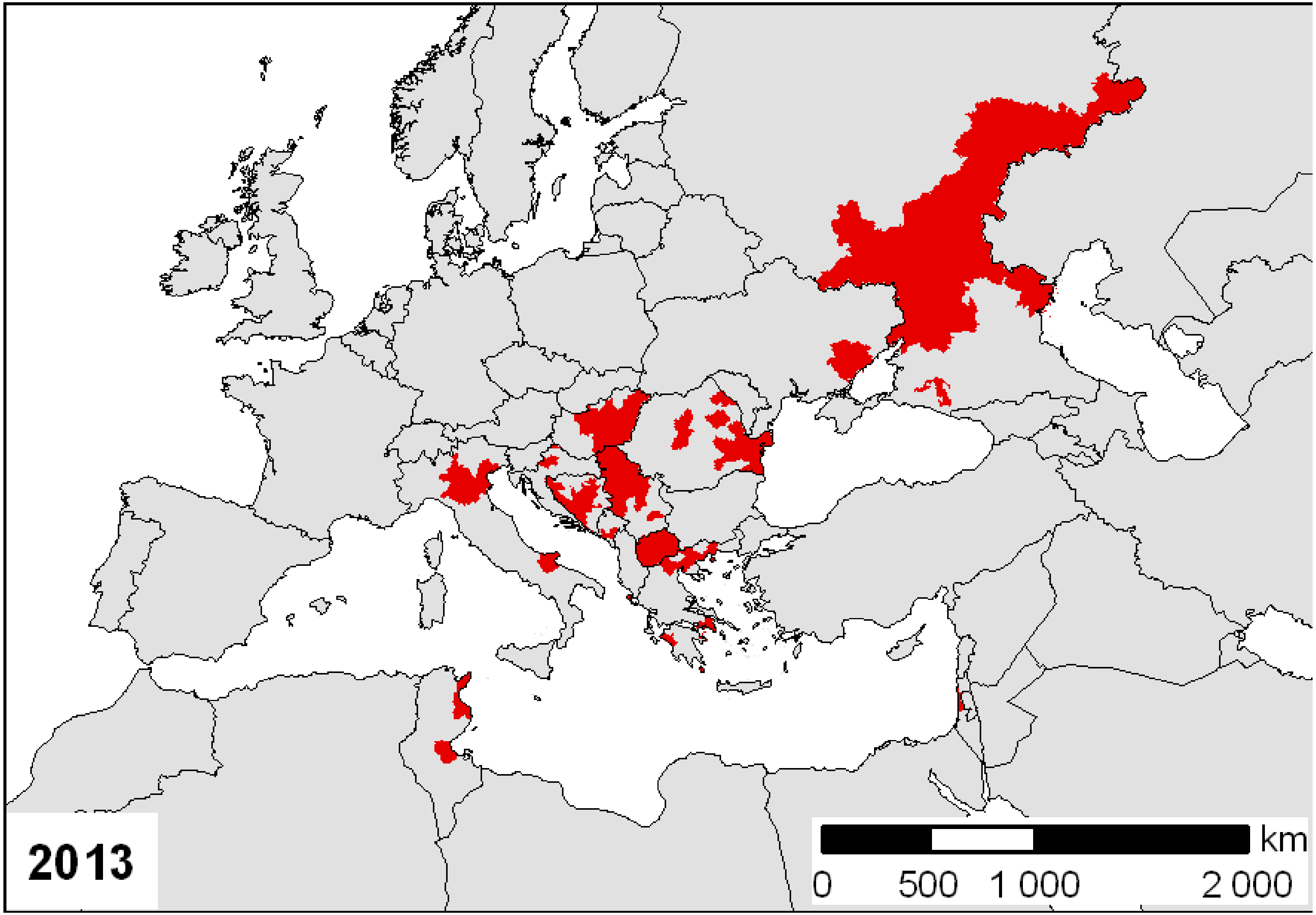
A multi-host disease

- Mechanisms of transmission ?

Environmental determinants



West Nile in Europe



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PLOS | ONE

Permissive Summer Temperatures of the 2010 European West Nile Fever Upsurge

Shlomit Paz[1], Dan Malkinson[1], Manfred S. Green[2], Gil Tsioni[1], Anna Papa[3], Kostas Danis[4], Anca Sirbu[5], Cornelia Ceianu[6], Krisztalovics Katalin[7], Emőke Ferenczi[7], Herve Zeller[8], Jan C. Semenza[8]*

1 Department of Geography and Environmental Studies, University of Haifa, Haifa, Israel, **2** School of Public Health, University of Haifa, Haifa, Israel, **3** Department of Microbiology, Medical School, Aristotle University of Thessaloniki, Thessaloniki, Greece, **4** Hellenic Centre of Disease Prevention & Control, Athens, Greece, **5** National Center for Surveillance and Control of Communicable Diseases, Bucharest, Romania, **6** Cantacuzino National Institute for Research and Development in Microbiology and Immunology, Bucharest, Romania, **7** National Center for Epidemiology, Budapest, Hungary, **8** European Center for Disease Prevention and Control (ECDC), Stockholm, Sweden

Abstract

Background: In the summer of 2010, Europe experienced outbreaks of West Nile Fever (WNF) in humans, which was preceded by hot spells. The objective of this study was to identify potential drivers of these outbreaks, such as spring and summer temperatures, relative humidity (RH), and precipitation.

Methods: Pearson and lag correlations, binary and multinomial logistic regressions were used to assess the relationship between the climatic parameters and these outbreaks.

Results: For human morbidity, significant (<0.05) positive correlations were observed between a number of WNF cases and temperature, with a geographic latitude gradient: northern ("colder") countries displayed strong correlations with a lag of up to four weeks, in contrast to southern ("warmer") countries, where the response was immediate. The correlations with RH were weaker, while the association with precipitation was not consistent. Horse morbidity started three weeks later than in humans where integrated surveillance was conducted, and no significant associations with temperature or RH were found for lags of 0 to 4 weeks.

Conclusions: Significant temperature deviations during summer months might be considered environmental precursors of WNF outbreaks in humans, particularly at more northern latitudes. These insights can guide vector abatement strategies by health practitioners in areas at risk for persistent transmission cycles.

Citation: Paz S, Malkinson D, Green MS, Tsioni G, Papa A, et al. (2013) Permissive Summer Temperatures of the 2010 European West Nile Fever Upsurge. PLoS ONE 8(2): e56398. doi:10.1371/journal.pone.0056398

Objectives

- ECDC public tender OJ/2012/02/16-PROC/2012/015:

MoBoD: Indicative Precursors of Mosquitoes-borne Disease Outbreaks in Europe

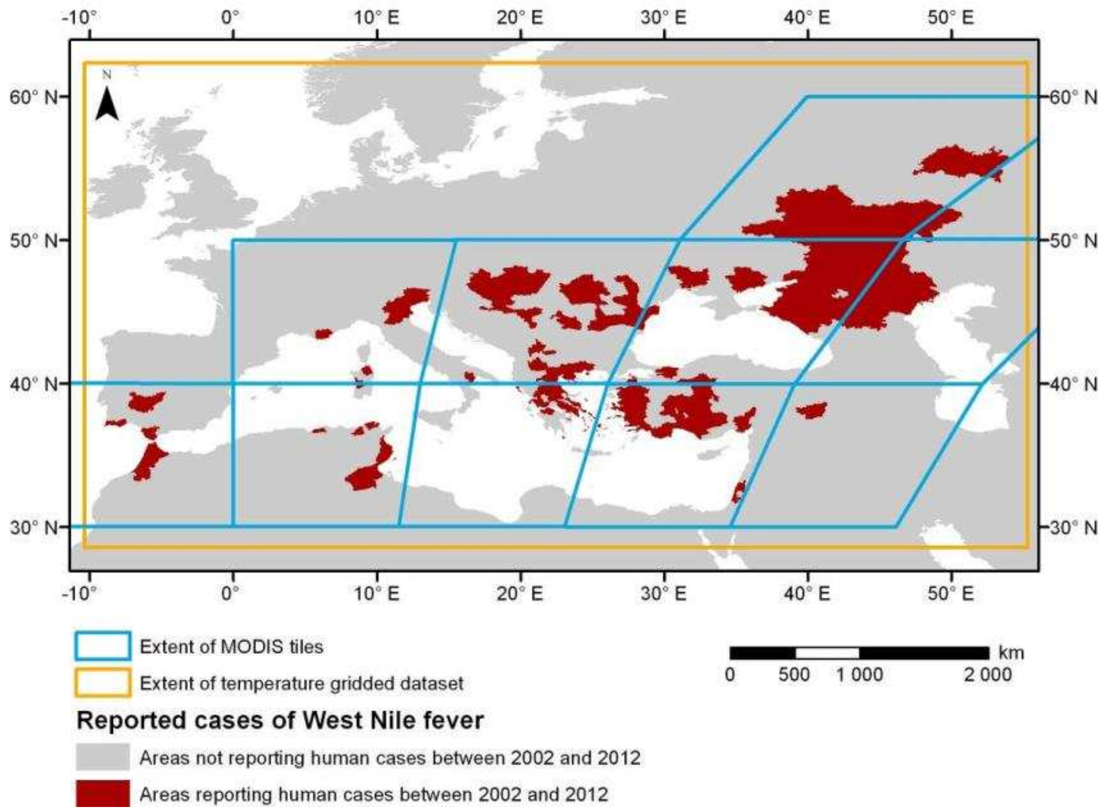
-> « ***to contribute to the understanding of mosquitoes-borne disease transmission in Europe, with a focus on the possible environmental drivers of WNF outbreaks*** »

- Specific objectives:

1. Provide relevant meteorological, environmental, host- and vector- population determinants of WNF
2. Carry out a multivariate analysis to identify risk factors for WNF in Europe
3. Build a prediction model including remotely sensed environmental and climatic variables to forecast WNF outbreaks in Europe

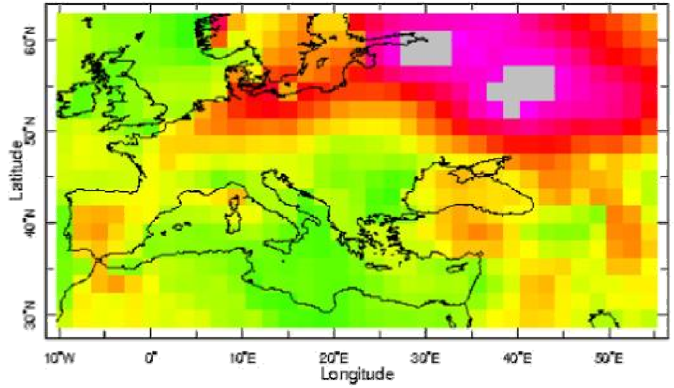
Epidemiological data

- Variable to explain:
  - Occurrence of confirmed cases at district level
  - 1113 spatial units
  - Retrospective / 12 years
- Dataset for training:
  - 2002-2011
- Dataset for validation:
  - 2012
  - 2013

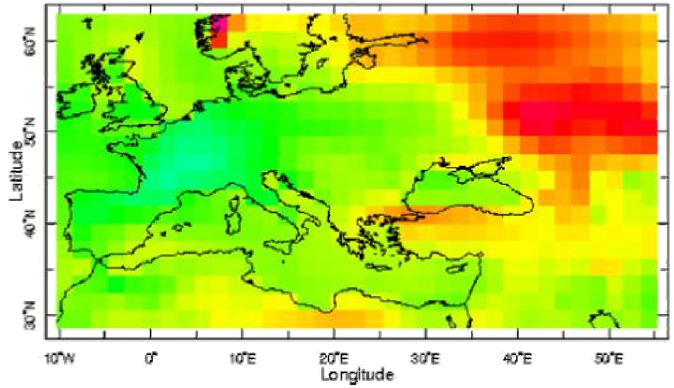


Explicative variable: Temperature ano.

- Monthly surface temperature anomalies
  - NOAA NCEP-NCAR database
  - 1981-today

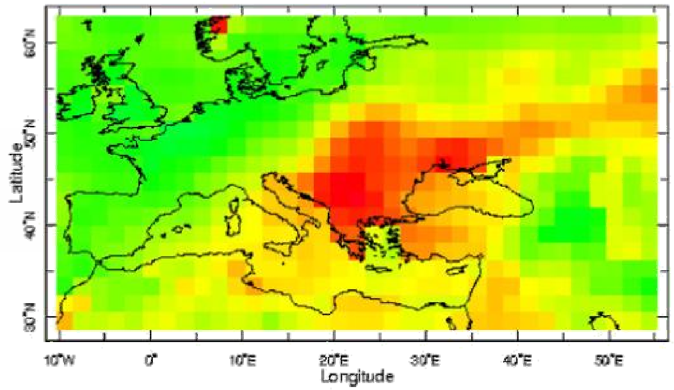


Jul 2010

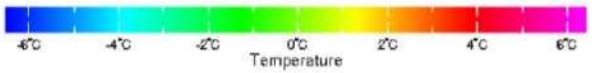


Jul 2011

NOAA NCEP-NCAR CDAS-1 MONTHLY Diagnostic surface temp anomalies Data Files

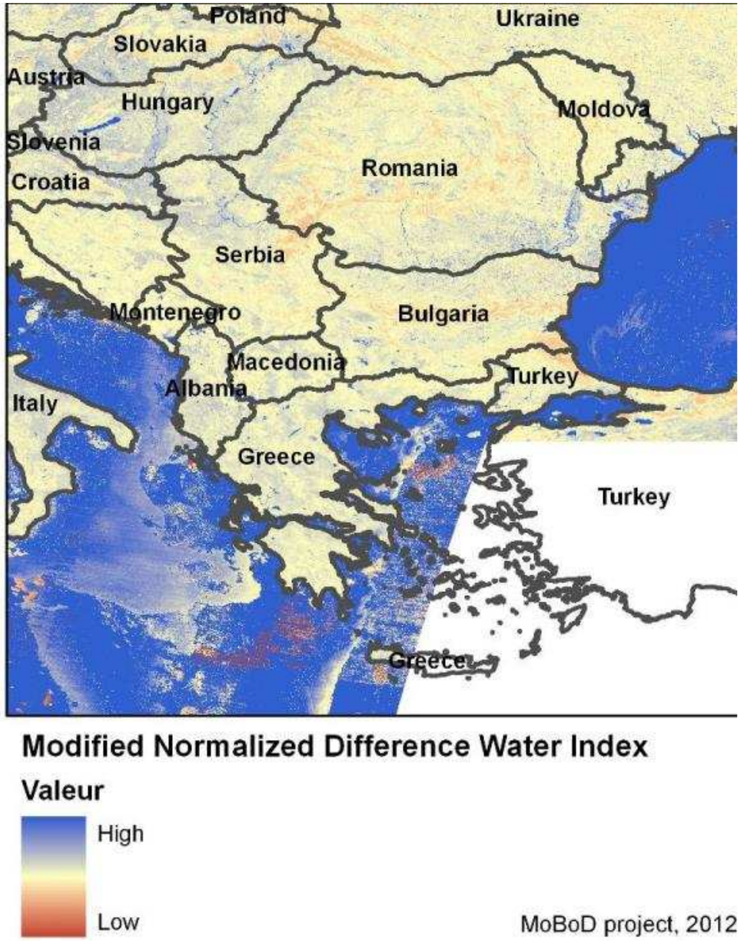


Jul 2012



Vegetation and Water indices

- Temporal series of MODIS images
  - MOD09A: Surface Reflectances
  - 8 days
  - Pixel size: 500 m x 500 m
  - 2002 – today



- Calculation of spectral indices:
  - NDVI: Normalized Difference Vegetation Index
  - MNDWI: Modified Normalized Difference Water Index

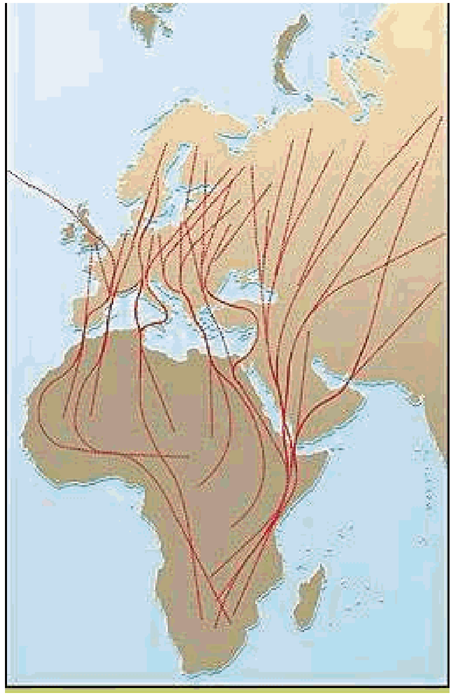
- Calculation of NDVI and MNDWI **anomalies** compared to the average of 2002-2011 period

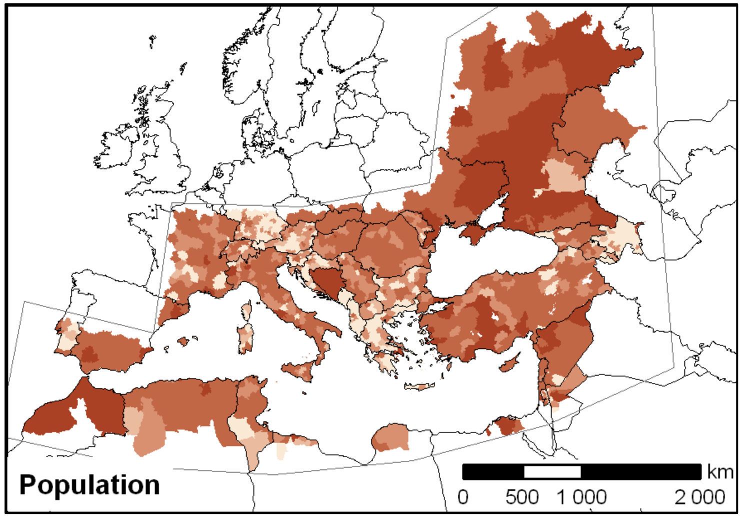
NDVI = (NIR-R)/(NIR+R)

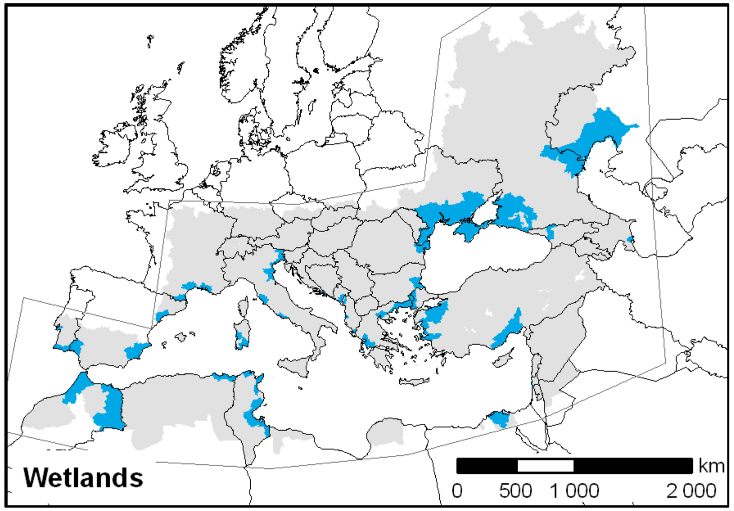
MNDWI = (G-SWIR)/(G+SWIR)

Other explicative variables

- Population data
- Passerine bird migration routes
- Main wetlands
  (Ramsar data base)







Overwintering index

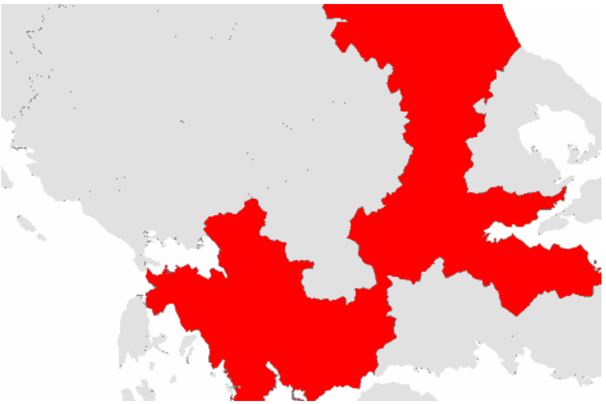
West Nile Virus in Overwintering *Culex* Mosquitoes, New York City, 2000

Roger S. Nasci,* Harry M. Savage,* Dennis J. White,† James R. Miller, ‡ Bruce C. Cropp,* Marvin S. Godsey,* Amy J. Kerst,* Paul Bennett, § Kristy Gottfried,* and Robert S. Lanciotti*

2009 West Nile disease epidemic in Italy: First evidence of overwintering in Western Europe?

F. Monaco*, G. Savini, P. Calistri, A. Polci, C. Pinoni, R. Bruno, R. Lelli

- λ: synthetic index of WNF outbreak occurrence in the neighborhood of a district, year - 1



$$\lambda_{i,j} = \frac{\sum_{k=1}^{n_j} y_{i-1,k} . w_{jk}}{n_j + 1}$$

yi,j: infected status of district *j*, year *i* (0: 'non infected'; 1: 'infected');
n_j: number of neighbouring districts of district j;
weight w_{jk} given to district k is 1 if k≠j and 2 otherwise

Statistical analysis

- Univariate analysis
- Co-linearity analysis
- Multivariate logistic regression model
  - Backward model selection
  - Akaike's Information Criterion (AIC)
  - Bootstrap procedure
- R freeware

Results

Table S1. Results of univariate analysis: significant variables in univariate screening analysis at 0.05 p-value

Covariate	Estimate	p-value
λ	4.65	0.0000
TMPAUG	0.47	0.0000
WETLAND	1.63	0.0000
MNDWI21	0.94	0.0000
TMPJUL	0.35	0.0000
POP	$2.27\ 10^{-7}$	0.0000
MNDWI20	0.54	0.0000
MNDWI22	0.52	0.0001
MNDWI15	0.48	0.0003
MNDWI27	0.50	0.0014
NDVI21	-0.09	0.0040
NDVI20	-0.09	0.0080
NDVI22	-0.08	0.0108
MNDWI12	0.35	0.0122
NDVI30	-0.08	0.0133
NDVI29	-0.07	0.0249
MIGRAT WEST EAST	 0.57 1.53	 0.0250 0.0000
MNDWI26	0.29	0.0297
NDVI18	-0.08	0.0316
NDVI19	-0.07	0.0331
MNDWI18	0.27	0.0374
TMPFEB	0.06	0.0436

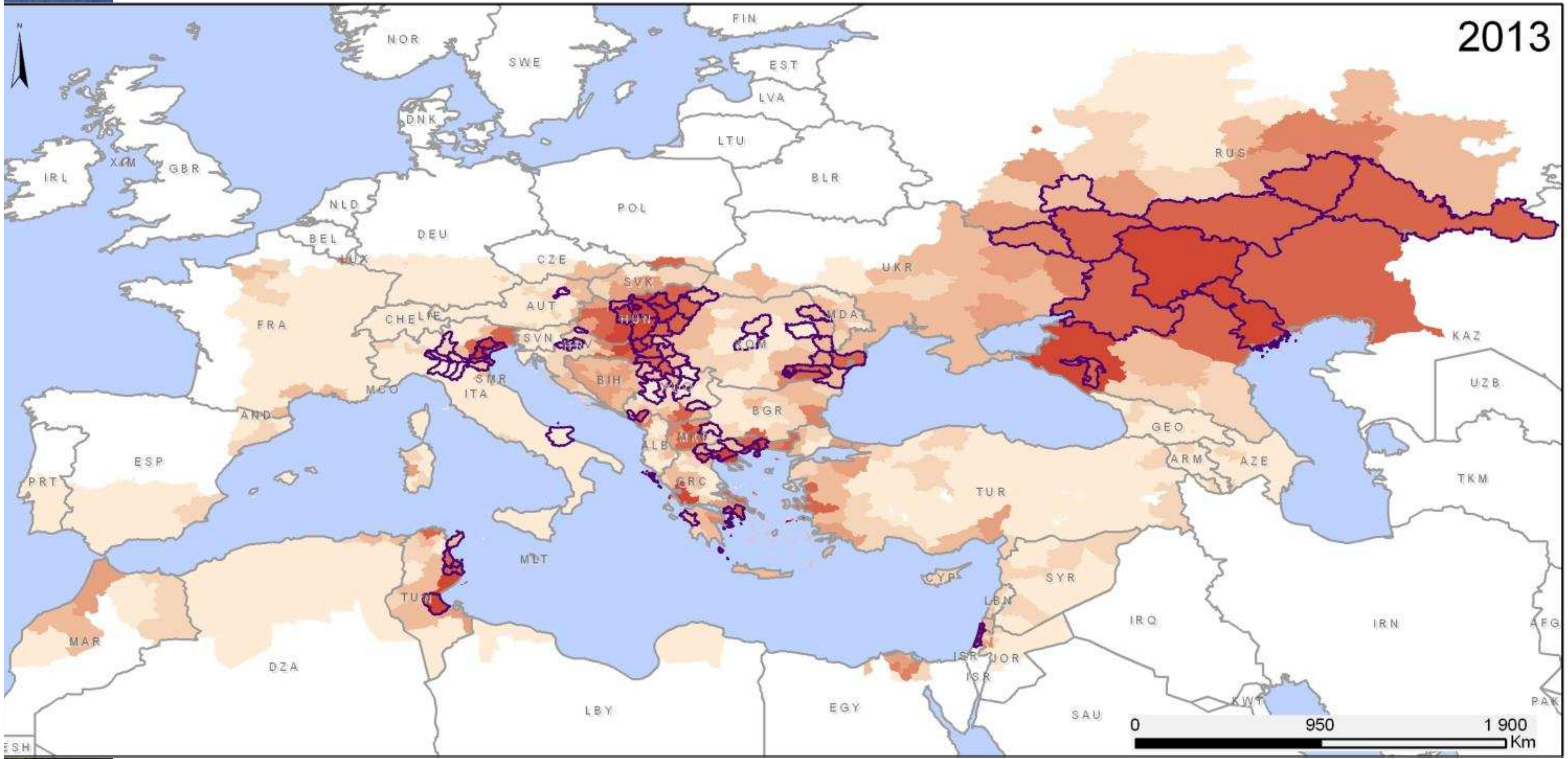
Results

Risk factors:

- Anomaly of temperature in July
- Anomaly of water index, 21st MODIS-8 day period (June 9-16)
- Overwintering index λ
- Presence of wetlands
- Presence of passerine migratory routes
- Population

	Parameter	p-value
Intercept	-5.85	-
TMPJUL	0.37	**$<10^{-7}$**
MNDWI21	1.14	**$<10^{-15}$**
λ	5.06	**$<10^{-15}$**
WETLANDS		
Absence		
Presence	1.38	**$<10^{-7}$**
MIGRATION		
Western path		
Eastern path	1.04	**$<10^{-7}$**
POPULATION	**$1.66\ 10^{-7}$**	**$<10^{-2}$**

Results



Predicted probability of WNF infection:

Areas reporting WNF cases:

Human outbreaks

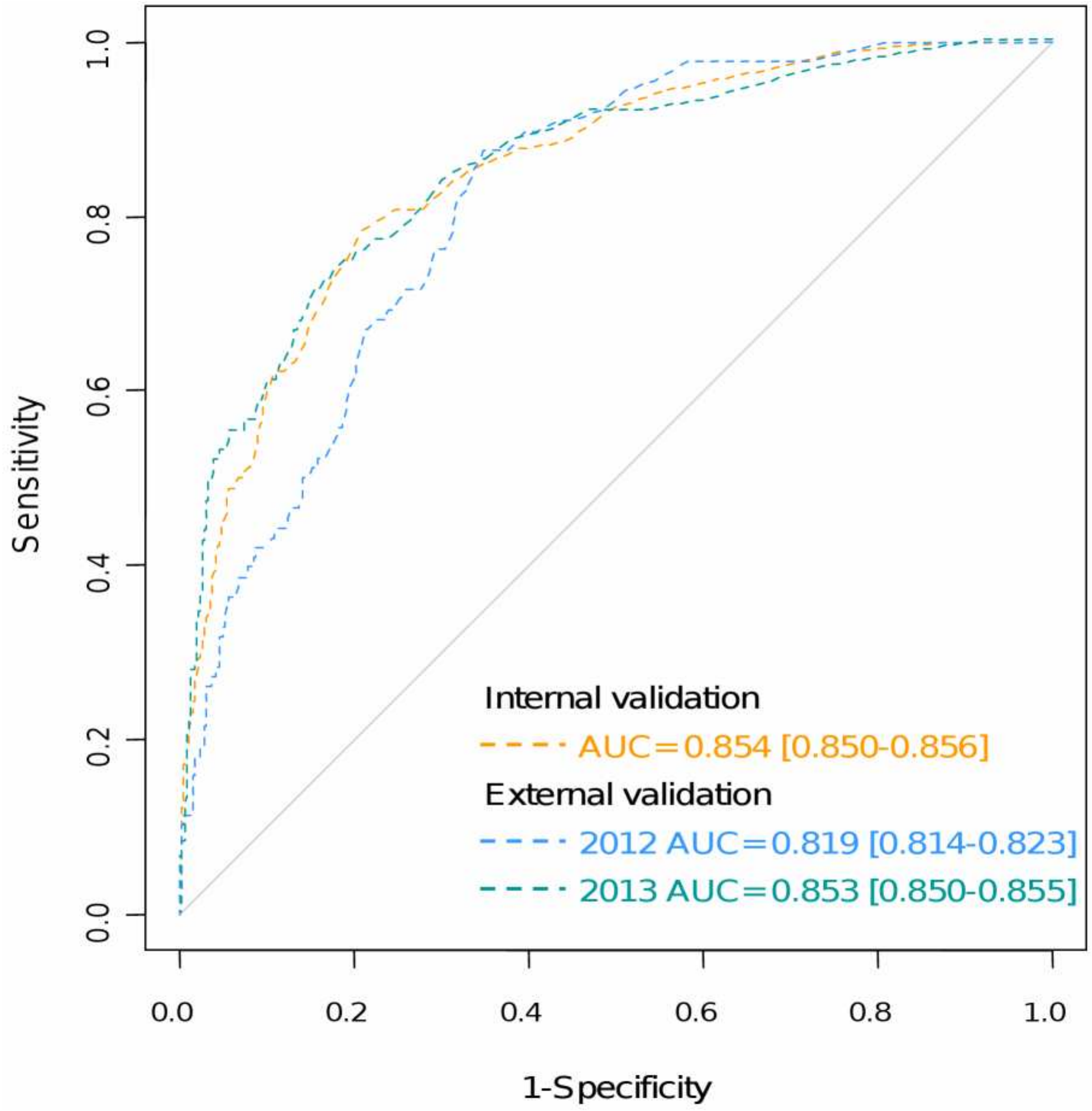
0 - 0.01
0.01 - 0.02
0.02 - 0.05
0.05 - 0.07
0.10 - 0.25
0.25 - 0.50
0.50 - 0.75
0.75 - 1

No prediction

Validation

Internal (2002-2011) and external (2012-2013) validations:

-> Good predictions!



Discussion

- Understanding
  - Temperature, wetlands, water index ~ favourable conditions for mosquito-borne transmission
  - Overwintering index
  - Migratory path: Eastern path more at risk?
  - Temporal and spatial heterogeneity in risk of WNF outbreak occurrence
  - Increase in the risk of outbreak occurrence

- Predicting?
  - A lot of uncertainties
  - Biases in surveillance, underreporting,…
  - *Processes:* Biological knowledge on virus, vectors and hosts needed

Discussion

- To be continued…
  - Other environmental variables: landscape indices, bird and mosquito distribution
  - Human activities, practices as risk factors
  - Studies at local scale
  - Incidence data
  - Other modelling approaches
  - …

- Field and experimental studies required

Conclusions

- WNV: a great challenge for mosquito-borne disease surveillance at the European and country scale
- European/international studies
- E3 portal
  - Sharing data, models, methods, …

Acknowledgments

- 2010 – onwards: data collection of West Nile distribution (Members states, candidates countries and surrounding states) by ECDC (emerging vector-borne disease program - Laurence Marrama, Epidemic intelligence team - Alastair Donachie)
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- B. Durand, ANSES
- EDEN teams


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annelise.tran@cirad.fr